Integrated Circuits Low Voltage Technology Issues
and
Obsolescence Implications

Author: Philip E. Stover, Ph.D., Universal Technology Corporation
e-mail: **pstover@utcdayton.com**

Introduction

Many modern integrated circuits operate at low voltage, and technology trends forecast the requirement for even lower voltages. Providing that low voltage is a challenge for designers of new systems, but for those who must replace obsolete parts with newer technology the problem can also be daunting. With the significant decline in the military semiconductor market, the defense industrial base has little leverage to control parts obsolescence issues and one result is that commercial devices will, of necessity, be used in military systems. There are many problems associated with adapting to the use of parts that do not meet the operational and environmental requirements of the military system. The low voltage issue addressed in this paper is only one of these problems. This paper contains:

- A brief power supply historical account,
- Air Force Research Laboratory efforts addressing specific issues
- Low Voltage Considerations for Addressing Obsolescence
- Ongoing Industry Initiative
- Challenges or “Where to from here”?

Brief Power Supply History and Background

Early aircraft had very crude electrical systems. The generators were given special attention because they were driven by the aircraft’s engines but, the rest of the electrical system had to be fit into the airframe wherever possible. At that time, the major loads were motors and other electromechanical components. As the power systems became more complex, system architectures and bus structures were developed to provide for safety and control and to assure that critical loads were the last to lose power in case of emergencies. The power system designer had an arm’s length relationship with the electronics system designer who would use only a small percentage of the power generated. Electrical power was bussed around the airplane at high voltage to minimize the current and thereby to keep conductor weight and cooling requirements low. Direct current power was provided in electronics bays at voltages that were selected to satisfy major loads and any electronics loads requiring low voltages were forced to install voltage regulators or converters.

As we approach the millennium, the situation has changed little. High voltage power will still be delivered to electronics bays and power supplies will still power busses or back-planes at some intermediate voltage. The thing that has changed is that some of the power will be utilized by integrated circuits that require very low voltages. Producing low voltages to supply a number of circuit cards is an obvious option but the weight and efficiency penalties incurred may make on-card power supplies a preferred option.

Air Force Research Laboratory (AFRL) Efforts

The requirement for low voltages to power integrated circuits has been recognized as an inevitable problem for a long time. In the mid 1980's, the Very High Speed Integrated Circuit (VHSIC) Program office established programs to develop light-weight power supplies that could be mounted on circuit boards. The first phase of the VHSIC program revealed that power supply technology had to be advanced to keep power supply weight and size from diminishing the gains provided by the new technology. Integrated circuit design rules were at 1.25 microns and the power standard was 5.5 volts. Contractual efforts (identified in Figures 1 and 2) to dramatically improve power supply technology started in 1987 and ran through 1996.. These programs addressed devices, topology and packaging.

Historical Perspective

VHSIC Related Power Supply Programs

General Goals: 50 w, 1 in^3,
50 volt to 5 volt, 0.18 in high

Prior art: 3 – 5 watts/in^3

VHSIC Advanced Power Supply, WRDC-TR-89-5050
Unisys Corporation

Low Voltage Power Supply, WRDC-TR-90-5022
AT&T Bell Laboratories

Fifty Watt per Cubic Inch Power Supply Development
Texas Instruments, WDRC-TR-90-5025

Figure 1

Historical Perspective

Recent Programs

High Density, High Efficiency, Card-Mounted Power Supply
Virginia Power Technologies Inc., WL-TR-97-1106

Above 100MHz Power Rectification, AFRL-SN-WP-TR-1998-1008
General Electric Company

Compound Materials for Power Device Applications
AFRL-SN-WP-TR-1998-1089, Honeywell and General Electric

Figure 2

Sub-micron design rules of VHSIC II pushed the voltage required to 3.3 volts but it became evident that a new standard voltage to replace 5.5 volts was not to be. The technology-driven requirements as well as power supply technology were changing too fast. The design approach of treating the power supply as an afterthought was no longer acceptable. The VHSIC plan was to follow these programs with low-voltage-technology development programs. However, support for these programs was cut before the low-voltage work could be started. The Air Force Research Laboratory, Sensors Directorate (AFRL/SN) point of contact for details about these programs and related power supply technology is Mr. George High, 937-255-4557, extension 3441.

The Air Force programs demonstrated units with internal switching frequencies up to 100 MHz but, for various technical reasons, today's technology tends to use 500 KHz to one MHz internal frequencies. Card level supplies are becoming quite common and 5.5-volt to 3.3-volt converters can be obtained from a number of sources. As the feature size of the elements on integrated circuits become smaller, voltage will continue to decrease and the supply of that low-voltage power will, of necessity, be an integral and often difficult part of the electronic system design.

The technology needed to address power supply issues becomes more and more challenging as the voltage drops and the decrease in operating voltage is an unavoidable result of the decreases in device feature size. As the devices on semiconductor integrated circuit chips get smaller, the operating voltages that are required across the devices to achieve control without inducing breakdown get smaller. At the same time, conductors on the chip get closer together and the voltages on these conductors generate higher electric fields in the material between the conductors. To avoid over-stressing the inter-electrode material, voltages must be reduced. Both cost reduction and performance gain drive the trend towards smaller devices on more complex integrated circuits and the trend is not likely to change.

Many groups of people have a vested interest in developing the low voltage power supply technology. Integrated circuit fabricators will find their market restricted if it is difficult or expensive to power those devices. Circuit and system designers must provide the power for their designs and power supply manufacturers are vying for market share. The problem is complicated by the fact that there will not be a standard voltage in the same sense that 5.5 volts has been a standard. Each new device technology will have its own voltage requirements and the market dynamics that drive power supply business decisions will be evolving for some time.

As integrated circuits in existing systems become obsolete there is a motivation to consider replacing those parts with newer technology. New technology often offers higher performance at reduced weight and volume. The old technology may not even be available as manufacturers close unprofitable facilities. The design or selection of an integrated circuit with the required functionality must be accompanied by a scheme for providing proper power. No longer can the power supply problem be solved by selecting an off-the-shelf unit. The power architecture and hardware must be an integral part of the design.

Power supply technology is constantly evolving. Power supplies in the 3.0 volt to 3.5 volt range are readily available. Providing power for devices that operate below two volts will require some ingenuity. Each scenario will require a more or less unique design solution until families of designs can be developed. A dedicated power supply must be part of the new design or, if several replacement parts are involved, a new power architecture may be indicated. In such a case, the cost, space and cooling required for the power components must be considered part of the solution and the power/component package must compete with alternate solutions if any exist.

Low Voltage Considerations for Addressing Obsolescence

For a new system, design of a power system architecture will be addressed early in the overall electronic system design. For the resolution of obsolescence cases, the same degree of freedom will seldom exist. Back-plane voltages will usually be fixed, often at 48 volts or 70 volts. The device or devices being replaced, most commonly operating at 5.5 volts will determine the power available at the point of use. <u>The problem for the designer then, is not only replacing or enhancing the functionality of the obsolete part but also adapting the available power to provide the replacement integrated circuits with the power required</u>. Power supplies that operate on 5.5 volts and provide 3.3 volt output are common but it will usually be necessary to tailor the supply to the application.

Improved ways of providing power to integrated circuits have evolved in recent years. For instance, the technology for power supplies that produce 3.3 volts is maturing. Board level supplies with internal switching frequencies on the order of one megahertz have been demonstrated in the laboratory with specific power densities of about 190 watts/in^3. On-board supplies represent a very important design option because of the difficulty in transmitting 3.3 volt power over long (several feet) distances and through connectors. The trend is toward power conversion on the circuit board in discrete power supplies, in power conversion chips integral to a multi-chip module or on the integrated circuit that is the load. Generic technology will continue to evolve but off-the-shelf hardware will not be common and each application will usually require a custom design.

For replacement of obsolete parts, two of the most important issues for low voltage power supplies are size and efficiency.

- **<u>Size</u>**. Size can determine the efficacy of a replacement strategy. If the power supply and the replacement part will not fit in the space allocated for the obsolete part, the power supply will have to be remotely located and the routing of power wires may be difficult enough that this resolution alternative is not practical. Replacement of a number of devices with a single integrated circuit or multi-chip module may be necessary to provide the space required.

- **<u>Efficiency</u>**. Thermal considerations have always been of particular concern to the power supply designer. The situation is exacerbated by the fact that low-voltage supplies are inherently inefficient, especially below three volts. Power lost due to low power-supply efficiency may be a problem if the system is on a tight power budget but it is even more likely that removal of the heat that results from low efficiency will present a serious problem. Active cooling or heavy heat sinks must be employed to dissipate heat because elevated temperatures can shorten the life of integrated circuits and capacitors. Heat pipes are becoming common as a means of transferring the heat to a location where it can be more readily dissipated. The removal of heat must therefore be addressed by any design that proposes to replace a high-voltage part with a lower-voltage part. In existing systems that are already thermally limited, this could become a prohibiting factor.

It is not practical to offer specific resolution alternatives for an obsolescence case or class of cases, but the following considerations should be useful.

- **Power System Architecture.** Be sure that the provisions for providing power to the new part or parts are adequately addressed. All available power sources should be considered and, in some cases, it may be desirable to power multiple loads in addition to the replacement part.

- **Compatibility.** Be sure that the power specified meets all the requirements of the load. Voltage and power requirements are often not sufficient.

- **Heat.** Be sure thermal considerations are adequately addressed. It will not be uncommon for the new power supply and part to generate more heat than the obsolete part.

- **Electromagnetic Interference (EMI).** Be sure EMI is considered. A power supply module with internal switching frequencies approaching one MHz can be a source of EMI that could have a deleterious effect on the replacement part as well as on neighboring parts and circuits.

- **Technology.** Power supply technology is changing and the technological approach that is most advantageous to a particular case may not be obvious. Contacting several leading companies is highly recommended.

Ongoing Industry Initiative

The P1515 committee of the Institute of Electrical and Electronics Engineers (IEEE) is in the process of submitting Language as well as Test Methods and Test Conditions documents to the main body of the IEEE for balloting. That committee has a charter to develop standard definitions of power supply terms, to establish standard testing procedures for power supplies, and to define test conditions. The progress of this committee should be monitored by anyone involved in resolving an obsolescence case that requires a power supply. Whether the person resolving an obsolescence case buys a power supply off the shelf or has one custom designed, it will be important that operational characteristics be adequately specified. Information on the progress of the committee and the list of terms can be found on the Internet at http://grouper.ieee.org/groups/1515/ .

The IEEE also has a Power Electronics Module Interface Working Group (P1461) with a charter to develop recommended practices for power electronics module interfaces. This group addresses problems that arise because power electronics circuits are being packaged into modules at higher power densities with internal integration of control electronics. This project will establish guidelines for power module manufacturers and the user community so that power modules can be interfaced readily and unnecessary re-engineering cost can be avoided. This project is to develop recommended practices for power electronic modules as well as passive support circuitry, so that power modules can be interfaced more readily. The group will specify the way to interconnect circuit components. The results will enable modular architectures for redundant, scaleable and low-cost systems by using standard building block elements. The activity of this group can be found at http://grouper.ieee.org/groups/1461/index.html.

Challenges or "Where to from here"?

The requirement for low voltage power to feed new generations of integrated circuits is unavoidable. The preferred approach to providing for those requirements will be case dependent. Technology issues will quite often dominate the design approach with electrical interface, thermal, size, weight and electromagnetic compatibility considerations of critical importance. Business considerations cannot be ignored since cost and reliable, long-term sources for the new parts is important to life-cycle cost impacts on the system. A larger view may reveal that it may be desirable to replace circuit cards or higher level subassemblies.

In every instance there are a number of organizations and individuals involved in resolving obsolescence cases. No longer are these daunting challenges addressed by isolated functional tiers within the company. The company's economic success is dependent on the customer's financial backing derived from satisfaction with life-cycle costs. The trend is to ensure that **<u>all</u>** involved have the necessary information to make smart decisions. This means that designers, management, and customers must all be aware of technology and financial trade-offs.